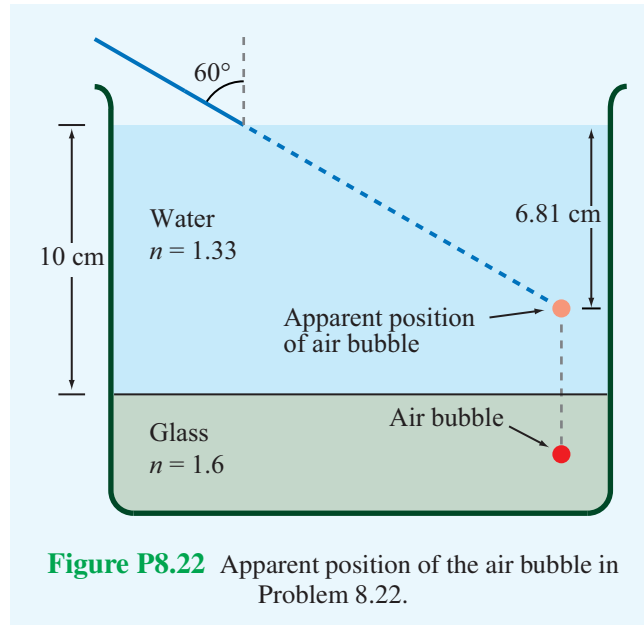


**8.22** Figure P8.22 depicts a beaker containing a block of glass on the bottom and water over it. The glass block contains a small air bubble at an unknown depth below the water surface. When viewed from above at an angle of  $60^\circ$ , the air bubble appears at a depth of 6.81 cm. What is the true depth of the air bubble?



**Figure P8.22** Apparent position of the air bubble in Problem 8.22.

**Solution:** Let

$$d_a = 6.81 \text{ cm} = \text{apparent depth,}$$

$$d_t = \text{true depth.}$$

$$\theta_2 = \sin^{-1} \left[ \frac{n_1}{n_2} \sin \theta_i \right] = \sin^{-1} \left[ \frac{1}{1.33} \sin 60^\circ \right] = 40.6^\circ,$$

$$\theta_3 = \sin^{-1} \left[ \frac{n_1}{n_3} \sin \theta_i \right] = \sin^{-1} \left[ \frac{1}{1.6} \sin 60^\circ \right] = 32.77^\circ,$$

$$x_1 = (10 \text{ cm}) \times \tan 40.6^\circ = 8.58 \text{ cm,}$$

$$x = d_a \cot 30^\circ = 6.81 \cot 30^\circ = 11.8 \text{ cm.}$$

Hence,

$$x_2 = x - x_1 = 11.8 - 8.58 = 3.22 \text{ cm,}$$

and

$$d_2 = x_2 \cot 32.77^\circ = (3.22 \text{ cm}) \times \cot 32.77^\circ = 5 \text{ cm.}$$

Hence,  $d_t = (10 + 5) = 15$  cm.

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